Single-phase Transformer.

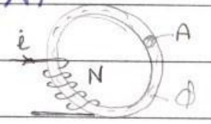
- To convert power from circuit to another at same frequency "primary ct. to secondary ct.".
- Transformer is static Device. & we use it in AC only.

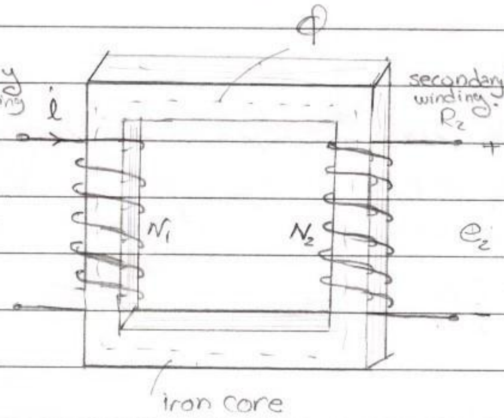
Transformer

Iron Core

good conductor for magnetic flux

$mmF = Ni$





Cupper core

$\therefore i = \frac{V}{R}$

$R = \frac{\rho L}{A}$

In cupper ρ is small and cheap.

$$\phi = \frac{Ni}{Reluctance}$$

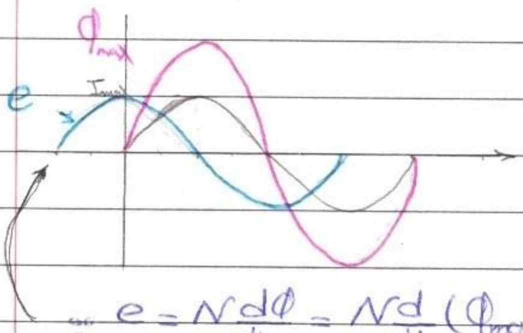
$$R_e = \frac{\ell}{\mu_0 \mu_r A}$$

μ_r = very high for iron

$\therefore R_e$ is very small

$R_e \downarrow\downarrow \rightarrow \phi \uparrow\uparrow$

$$\therefore e = N\frac{d\phi}{dt}$$



$i = I_{max} \sin \omega t$

$\phi = \phi_{max} \sin \omega t$

$$\therefore e = N\frac{d\phi}{dt} = N\frac{d}{dt}(\phi_{max} \sin \omega t) = \underbrace{N\phi_{max}\omega}_{e_{max}} \cos \omega t$$

$$e_{max} = N\phi_{max}\omega$$

$$e_{rms} = \frac{N\phi_{max}\omega}{\sqrt{2}}$$

$$e_{rms} = \frac{N \phi_m \omega}{\sqrt{2}} = \frac{2\pi f N \phi_{max}}{\sqrt{2}} = \sqrt{2}\,\pi f N \phi_{max}$$

$$e_{rms} = 4.44 f N \phi_{max} \quad \#$$

$$E_1 = 4.44 f N_1 \phi_{max}$$
$$E_2 = 4.44 f N_2 \phi_{max}$$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \quad \#$$

if $N_1 > N_2$ step down Transf.
if $N_1 < N_2$ step up Transf.

$$R_1 = \left(\frac{N_1}{N_2}\right)^2 R_2 \quad \#$$

types of load.

over load	زيادة عن الحد وده مش موجود
full load	كل الأجهزة اشتغلت
half load	نص الأجهزة
low load	مفيش أي حاجة شغالة

Ex: 10 KVA , 250/125 V Transf.

sol: $\therefore V_{N_1} = 250$

$V_{N_2} = 125$

$10 \times 10^3 = V_1 I_{N_1} = V_2 I_{N_2}$

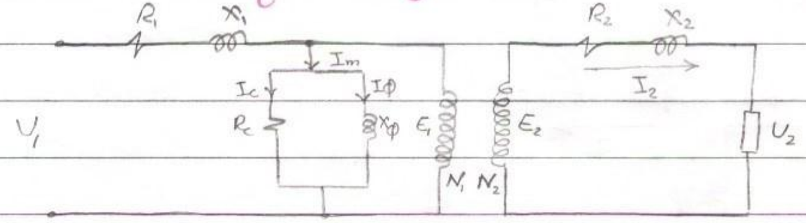
$= 250 \times I_{N_1} = 125\, I_{N_2}$

$I_{N_1} = 40\,A$

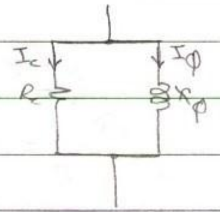
$I_{N_2} = 80\,A$

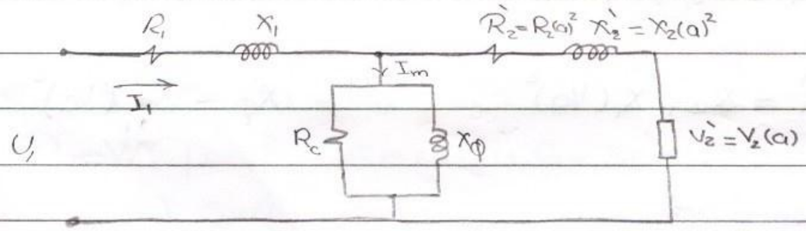
Note: To measure AC $\rightarrow$ RMS
DC $\rightarrow$ average

Equivalent circuit of a transformer.



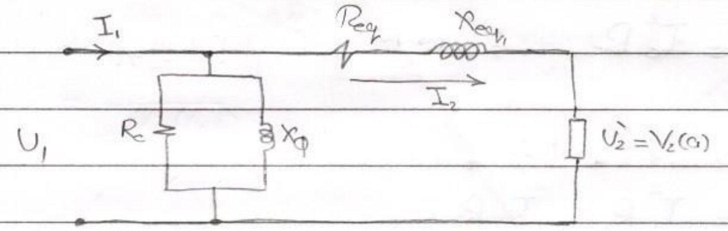
a- Refered to primary side.





R_c لا تخضع لقانون ohm.

Exact Eeqivalent Circuit.



Approximate Eeqivalent circuit.

$$R_{eq_1} = R_1 + R_2' = R_1 + R_2(a)^2$$

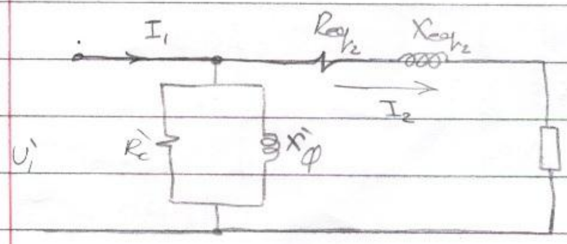
$$X_{eq_1} = X_1 + X_2' = X_1 + X_2(a)^2$$

$$V_2' = V_2(a)$$

$$I_2' = I_2 \div a$$

where $a = \frac{N_1}{N_2}$

Refered to secondary side.



أموّق اشتغل referred
الـ Pinary والـ second.
دة معروفين لما Given

$$a = \frac{N_1}{N_2}$$

$$V_1' = V_1 \div a$$

$$R_{eq_2} = R_2 + R_1' = R_2 + R_1 (1/a)^2 \qquad R_c' = R_{c_1} (1/a)^2$$

$$X_{eq_2} = X_2 + X_1' = X_2 + X_1 (1/a)^2 \qquad X_\phi' = X_{\phi_1} (1/a)^2$$

Losses.

1- Iron losses

$$P_i = I_c^2 R_c$$ "Fixed" لأنه الجهد عليه ثابت

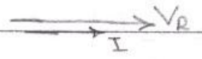
2- Copper losses:-

$$P_{cu} = I_1^2 R_1 + I_2^2 R_2$$
$$= I_1^2 R_{eq_1} = I_2^2 R_{eq_2} \;\#$$ "Variable"

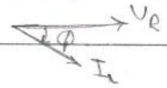
Total loss $= P_i + P_{cu}$

Power factor:-

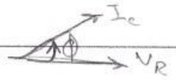
1- unity power factor $Z_L = Z_R$



2- lagging power factor: $Z_L = R + jX_L$

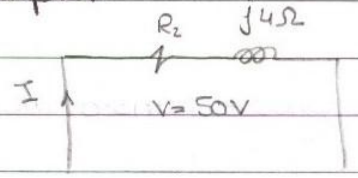


3- leading power factor: $Z_L = R - jX_C$



$$PF = \cos\phi$$

example:-   ex: للموضوع ب



Sol:

$Z_L = 3 + j4 = 5 \angle 53.13^\circ$

$I = \frac{V}{Z_1} = \frac{50\angle 0}{5\angle 53.13^\circ} = 10 \angle -53.13^\circ$

$P.f. = \cos 53.13 = 0.6$ lagging

$S = V.I = 50 \times 10 = 500$ VA

$P = V.I \cos\phi = 50 \times 10 \times 0.6 = 300$ W

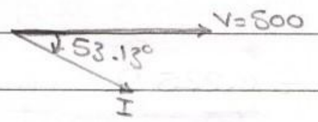
$V.I \sin\phi = 50 \times 10 \times 0.8 = 400$ VAR

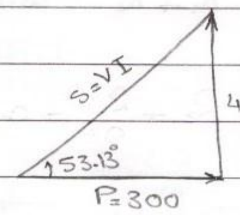
$\cos^2 x + \sin^2 x = 1$

$\sin x = \sqrt{1 - \cos^2 x}$

$= \sqrt{1 - (0.6)^2}$

$= 0.8$





Example:-

A 5KVA, 500/250 V single phase transformer has the following parameter.

$R_1 = 1/2\,\Omega$, $X_1 = 0.6\,\Omega$, $R_2 = 0.1\,\Omega$, $X_2 = 0.15\,\Omega$,
$R_c = 5K\Omega$ & $X_\phi = 500\,\Omega$

Required:-

1) R_{eq_1} & R_{eq_2}
2) cupper losses at full load & Iron losses
3) total losses at half load
4) effeciency at full load & half load at 0.8 P.f. lagging.

sol:-

$$a = \frac{N_1}{N_2} = \frac{500}{250} = 2$$

(1) $R_{eq_1} = R_1 + R_2' = 1/2 + (0.1)(2)^2 = 0.9\,\Omega$

$X_{eq_1} = X_1 + X_2' = 0.6 + (0.15)(2)^2 = 1.2\,\Omega$

$$R_{eq_2} = R_2 + \frac{R_1}{a^2} = 0.1 + \frac{0.5}{4} = 0.225\,\Omega$$

$$X_{eq_2} = X_2 + \frac{X_1}{a^2} = 0.15 + \frac{0.6}{4} = 0.3\,\Omega$$

N.B $R_{eq_1} = R_{eq_2}(a)^2$

(2)

$5KVA = 5000 = 500\,I_{N_1} = 250\,I_{N_2}$

$I_{N_1} = 10\ A$

$I_{N_2} = 20\ A$

$P_{cu}|_{full} = I_N^2 R_1 + I_N^2 R_2 = (10)^2(0.5) + (20)^2(0.1) = 50 + 40 = 90\,W$

or

$P_{cu}|_{full} = I_{N_2}^2 R_{eq_2} = (20)^2(0.225) = 90\,W$

$P_{\substack{half\\load}} = P_{\substack{full\\load}}\,(1/4) = 22.5\ W$, with $(1/2)^2$ written above $(1/4)$

$$P_i = I_c^2 R_c$$

where $I_c = \dfrac{V}{R_c} = \dfrac{500}{5000} = 0.1\,A$

$$P_{iron} = (0.1)^2 \times 5000 = 50 \text{ watt}$$

$$\text{loss}\Big|_{\text{at full load}} = P_i + P_{cu} = 50 + 90 = 140\ w$$

at 50% load

$$\text{loss} = 50 + 22.5 = 72.5\ w$$

ال loss بالنسبة لل iron
ثابتة في ال F.L أو ال H.L

$$\eta = \frac{P_{out} \cdot pf}{P_{out} \cdot pf + \text{losses}}$$

$$\eta_{F.L} = \frac{5000 \times 0.8}{5000 \times 0.8 + 50 + 90} = 0.966 = 96.6\ \%$$

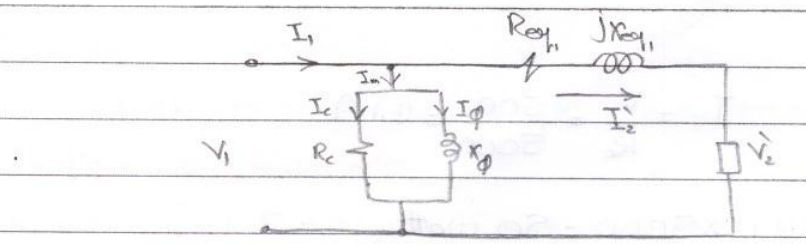
$$\eta_{H.L} = \frac{\frac{1}{2}(5000)(0.8)}{\frac{1}{2}(5000)(0.8) + 50 + 90(0.5)^2} = \frac{2000}{2072.5} = 96.5\ \%$$

[illegible]

$$\eta_{x\text{-load}} = \frac{x\,(KVA)(P.f)}{x\,(KVA)(P.f) + P_{iron} + P_{cu_{\text{full load}}}\,(x^2)}$$

$0 < x < 1$

$$X_m = \sqrt{\frac{P_i}{P_{cu_{Full}}}} \quad \leftarrow \quad \text{ماهي ال } X_m \text{ ؟؟}$$



عايزين نجيب بقى الـ Parameter اللى هى R_c & X_ϕ و R_{eq_1}

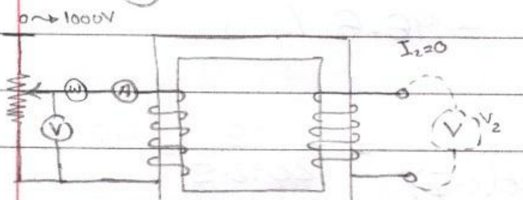
Parameters

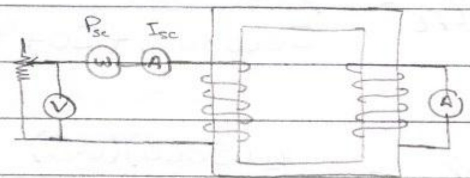
Iron part $R_c + X_\phi$ — open circuit test ← تجارب علشان أجيب → short circuit test — **Cupper part** $R_{eq_1} + X_{eq_1}$

O.C.T — ضم الثوابت — S.C.T

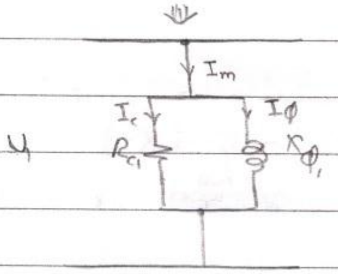
(HVS) high voltage side ← يعني عند (Primary)

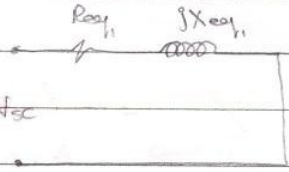
يعني مفتوح أى دى طالع فى (Secondary)





V_0	I_0	P_0	V_2
100			50
200			
500			250



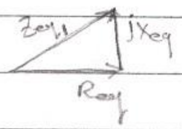


$P_{sc} = I_{sc}^2 R_{eq_1}$

$R_{eq_h} = ✓$

$V_{sc} = I_{sc} Z_{eq_1}$

$X_{eq_h} = \sqrt{Z_{eq_1}^2 - R_{eq_1}^2}$



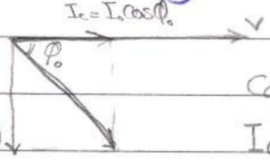
معنى نسيب الـ secn open أو أوصلها بـ voltmeter

O.C.T (HVS):

500V, 1A, 120W

بدل ما يقول (HVS) يقول Power transformer لأن المقاومة الداخلية العريض تكون ∞

secondary is open



$P_c = V_c I_c \cos\phi$ من

$\cos\phi = ✓$ $I_c = ✓$

$I_\phi = ✓$

بفضل أشغل الـ open C.t عند Primary لأنه بكدة أنا هبدأ أرفع الجهد لحد 250 بدل 500 وبكدة التيار عند الـ Primary صغير فبكدا بفضل يكون عند الـ sec.

هنا أهمل الدائرة بتاعة الـ iron لأن كان الـ 500V Volt كان ماشى تيار 1A وفى المرة دى الجهد هيكون 50V يبقى التيار 0.1A فممكن أهمل الدائرة

Example:- 10 KVA, 500/250 V, single phase transformer has a following test data:-

open circit test (O.C.T) (H.V.S) , 500 V, 1 A, 200 watt

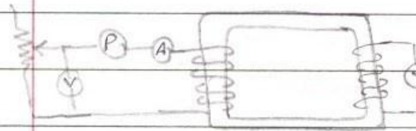
short circuit test (S.C.T)(L.V.S) , 25 V , 40 A , 600 watt

(1) Obtain the parameter of this transformer refered to primary & refered to secondary side.

(2) Obtain the max. effeciency at 0.8 P.f. lagging.

Sol:-

(a) O.C.T (HVS) — 500 V, 1 A, 200 watt



$P_o = V_o I_o \cos\phi$

$\cos\phi = \frac{200}{(500)(1)} = 0.4$

$\sin\phi = 0.96$

$I_c = I_o \cos\phi = 0.4 A$

$I_\phi = I_o \sin\phi = 0.96 A$

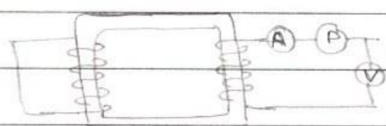
$R_{c_1} = \frac{V_o}{I_c} = \frac{500}{0.4} = 1250\ \Omega$

$X_{\phi_1} = \frac{V_o}{I_\phi} = \frac{500}{0.96} = 545.5\ \Omega$

$R_{c_2} = \frac{R_{c_1}}{a^2} = \frac{1250}{4} = 312.4\ \Omega$

$X_{\phi_2} = \frac{X_{\phi_1}}{a^2} = \frac{545.5}{4} = 136.4\ \Omega$

S.C.T (L.V.S) — 25 V, 40 A, 600 watt



$P_{sc} = I_{sc}^2 R_{eq_{r_2}} \rightarrow$

$R_{eq_{r_2}} = \frac{600}{(40)^2} = 0.375\ \Omega$

$V_{sc} = I_{sc} Z \rightarrow$

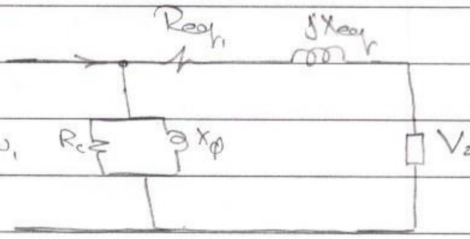
$Z = \frac{V_{sc}}{I_{sc}} = \frac{25}{40} = 0.625\ \Omega$

$X_{eq_{r_2}} = \sqrt{Z^2 - R_{eq_{r_2}}^2} = 0.5\ \Omega$

$R_{eq_h} = R_{eq_{r_2}} (a)^2 = 4 * 0.375$ #

$= 1.5\ \Omega$

$X_{eq_h} = X_{eq_h} a^2 = 2\ \Omega$ #



لما حد يقول H.V.S أو L.V.S دقة لازم أعرف انه الـ R والـ X اللي هطلع هتكون referred لأن نحن لو H.V.S يعني الـ X والـ R بتكون referred للـ Primary

L.V.S ← يعني هتكون referred to secondary.

(b)

$P_{in} = 200\,W$ "open ct."

or $I_c^2 R_c = 200\,W$

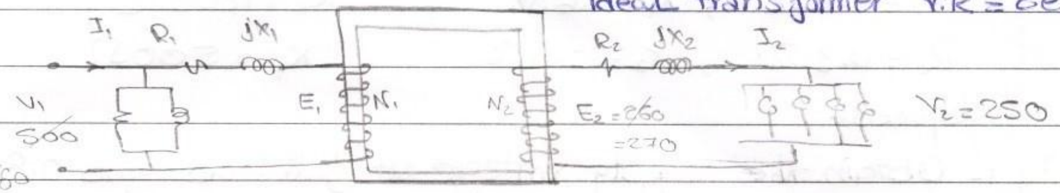
$$P_{cu(FL)} = I_{N_1}^2 R_{eq_{r_1}} = I_{N_2}^2 R_{eq_{r_2}}$$
$$= (20)^2(1.5) = (40)^2(0.375) = 600\,W$$

من هين بطلع ال Power تاعة ال ($Cu_{(FL)}$) تعطيني ياها تاعة ال Short ct. test.

Voltage Regulation : The change in the secondary voltage from no load to full load for the same primary voltage

* The voltage regulation is like the figure of merit of a transformer.

Ideal transformer V.R = zero.



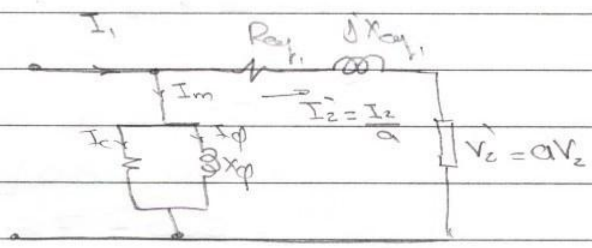
$E_2 = I_2 Z_2 + V_2$

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = a$$

$$* \; V.R = \frac{V_1 - V_2'}{V_2'} = \frac{580 - 500}{500} = \frac{80}{500} = 16\%$$

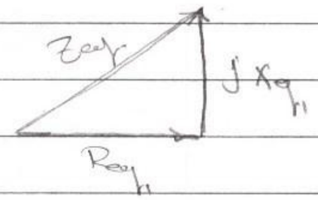
$$V.R = V_1 - V_2$$

$$V.R\,\% = \frac{V_1 - V_2'}{V_2'} * 100 =$$



$$I_1 = I_2 \angle \pm \phi_2 + \frac{V_1}{R_c} - j\frac{V_1}{X_\phi}$$

$$= a \pm jb = \sqrt{a^2 + b^2} \angle \pm \tan^{-1}\frac{b}{a}$$



$$V_1 = V_2' \angle 0 + I_2' \angle \pm \phi_2 \; Z_{eq_{r_1}} \angle \theta$$
$$= A + jB$$

$$V_1 = \sqrt{A^2 + B^2} \angle \tan^{-1} B/A = \phi_1$$

where $|Z_{q_{r_1}}| = \sqrt{R_{eq_{r_1}}^2 + X_\phi^2} \angle \tan^{-1} X_{eq_1}/R_{eq_1}$

$P_{in} = V_1' I_1 \cos\phi_1$

where $\phi_1 = \alpha + \beta$

$P_{out} = V_2 * I_2 \cos\phi_2$

ex8 -

Example: 10 KVA, 500/250 V, single phase transformer has the following parameter.

$R_1 = 1.2\Omega$, $X_1 = 1.6\Omega$ $R_c = 1200\Omega$

$R_2 = 0.3\Omega$, $X_2 = 0.4\Omega$ $X_\phi = 500\Omega$

Required:-

(V_1) 1- Obtain the supply voltage ~~at~~ full load and 0.8 p.f lagging

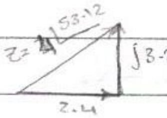
(I_1) 2. obtain the input current at this case.

$\left(\frac{V_1 - V_2'}{V_2'}\right)$ 3. obtain the voltage regulation.

sol:-

$R_{eq_1} = 1.2 + 0.3(2)^2 = 2.4\Omega$

$X_{eq_1} = 1.6 + (0.4)(4) = 3.2\Omega$



$V_1 = V_2' \angle 0 + I_2' \angle \phi\ Z \angle \theta$

$(250)(a) \rightarrow = 500 \angle 0 + (20 \angle -36.87)(4 \angle 53.13)$

$= 500 \angle 0 + 80 \angle 16.26$

$= 500 + 80[0.96 + j0.28]$

$= 500 + 76.8 + j22.4$

$= 576.8 + j22.4 = 577.23 \angle 2.22$

$V.R = V_1 - V_2' = 77.23V = \frac{77.23}{500} * 100 = 15.44\%$

$I_1 = I_2' + I_c + I_\phi$

$= 20 \angle -36.87 + \frac{577.23}{1200} - j\frac{577.23}{500}$

$= 16 - j12 + 0.48 - j1.75$

$\simeq 16.48 - j13.15 = 21.08 \angle -38.58$

$P_1 = V_1 I_1 \cos\phi = 577.23 * 21.08 * \cos(38.58 + 2.22) \approx 0.8$

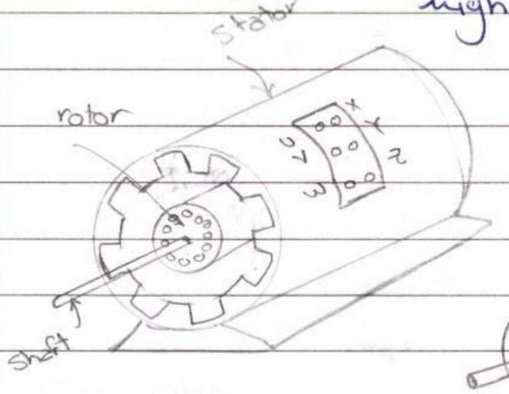
$= 9211.1\omega$

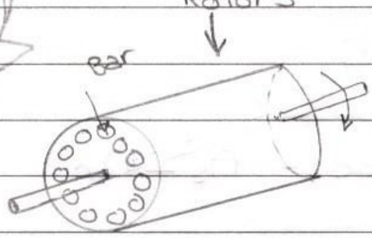
$P_{out} = V_2 I_2 \cos\phi = 250 * 40 * 0.8 = 8000$ watt

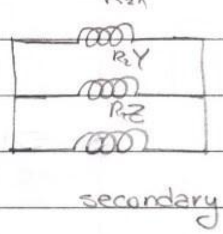
Chapter II
Three phase Induction Motors.

Stator + Rotor

(wound Rotor) high power | (squirrel cage Rotor) low power

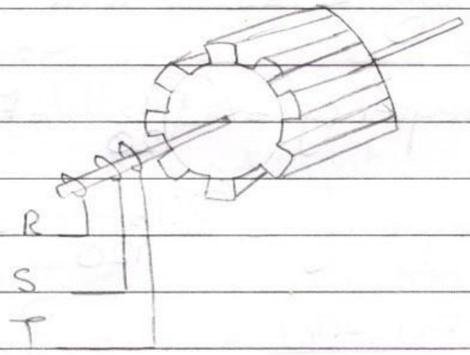




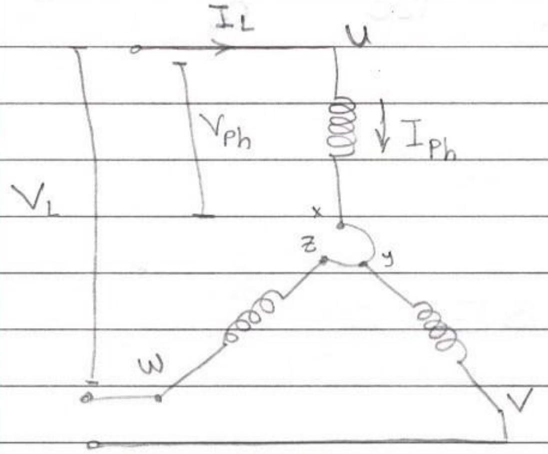


يتحمل تيار كبير

squirrel cage



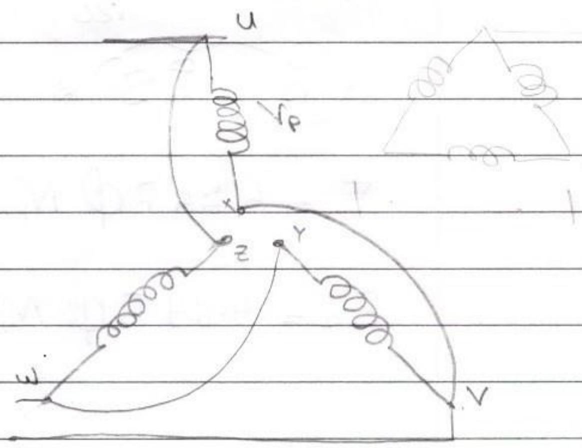
Star



$V_L = \sqrt{3}\, V_{ph}$

$I_L = I_{ph}$

Delta



$V_L = V_{ph}$

$I_L = \sqrt{3}\, I_{ph}$

Let slot $(S) = 12$

Poles $(P) = 2$

Phases $(m) = 3$

※ n_s : Synchronous speed $= \frac{120f}{P}$ rpm

$= \frac{120 * 50}{2} = 3000$ rpm

$emf = N \frac{d\phi}{dt}$

$F = Bli$

※ slip speed $= n_s - n_r$ rpm

※ $S = \frac{n_s - n_r}{n_s}$ $\quad 0 < S < 1$

at starting $S = 1$ and $n_r = 0$

※ stator frequency $= \frac{P n_s}{120} = f_1$

※ Rotor frequency $= \frac{P(n_s - n_r)}{120} = f_2$

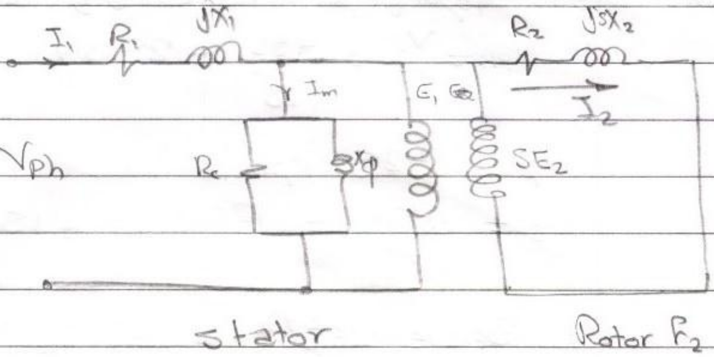
$\therefore f_2 = \frac{P(n_s - n_r)}{120} \times \frac{n_s}{n_s} = \frac{P n_s}{120} \cdot \frac{n_s - n_r}{n_s}$

$f_2 = f_1 S$ ※

$E_1 = 4.44 f_1 \phi N_{ph}$

$E_2 = 4.44 f_2 \phi N_{ph} \simeq S E_{20}$

Equivalent Circuit



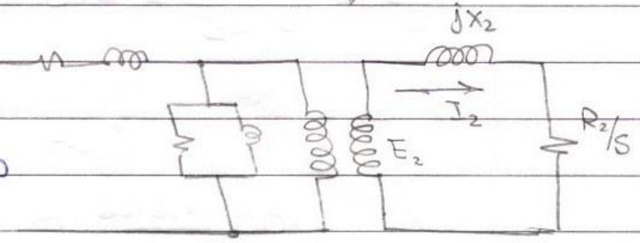
$$I_2 = \frac{SE_2}{R_2 + jSX_2}$$

$$= \frac{E_2}{\frac{R_2}{S} + jX_2}$$

$$\frac{R_2}{S} = R_2 + \underbrace{\frac{R_2}{S}(1-S)}_{R_m}$$

$$= R_2 + R_m$$

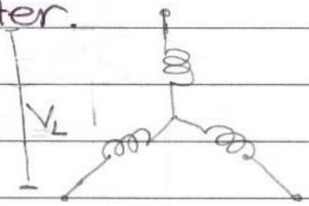
$\Downarrow$ resistance due to load.



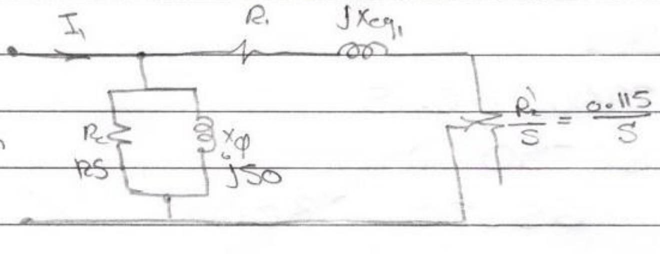
Examples:-

A 433V star connection four Pole 50HZ, 1425 rpm (Full load) Three phase induction motor has the following Parameter $R_1 = 0.1\Omega$, $X_1 = 0.3\Omega$, $R_2' = 0.115$, $X_2' = 0.4\Omega$, $R_c = 125\Omega$, $X_\phi = 50\Omega$, obtain

1- The slip at full load
2- The stator input Current and input power factor.
3- The full load efficiency if the fractional losses = 2.3
4- The starting Torque in newton meter.



حل المسألة دي في شرح الأول وبعد كده حل المسألة.



* لو مدالنيش الـ R_c فى إجابة اعطها بـ ∞

* دايماً الـ Volt اللى بيدهولى هو V_L ولو كان delta هيبقى الجهد هو هو

$$V_{ph} = \frac{V_L}{\sqrt{3}} = \frac{433}{\sqrt{3}} = 250\,V$$

$$n_r = 1425 \text{ rpm}$$

$$n_s = \frac{120f}{P} = \frac{120 * 50}{4} = 1500 \text{ rpm}$$

(a) $S_{F.L} = \frac{n_s - n_r}{n_s} = \frac{1500 - 1425}{1500} = 0.05 \text{ P.u} = 5\%$

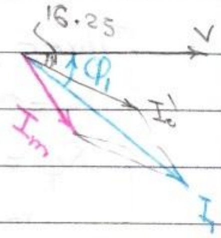
$$\frac{R_2'}{S} = \frac{0.115}{0.05} = 2.3\,\Omega$$

(b) $I_2' = \frac{V_{ph}}{(0.1 + 2.3) + j0.7} = \frac{250\angle 0}{2.4 + j0.7} = \frac{250\angle 0}{2.2\angle 16.26}$

$$= 100\angle -16.26 \text{ A} = 96 - j28$$

$$I_m = I_c + I_\phi = \frac{250}{125} - j\frac{250}{50} = 2 - j5$$

$$I_1 = I_m + I_2' = 98 - j33 = 103.4\angle -18.6 \text{ A}$$



دايماً الـ pf بتاعى ~ زاوية I_1

$$P.f = \cos\phi_1 = \cos 18.6 = 0.9477 \text{ lagging}$$

(c)

P_{in}

$P_{cu} + P_{core}$ $\quad$ $P_g = 3I_2'^2 \frac{R_2'}{S}$

P_{cu_2} $\quad$ P_m

P_f $\quad$ P_{out}

$$P_{in} = 3(250)(103.4)(0.9477)$$
$$= 73495 \text{ w}$$

$$P_g = 3I_2'^2 \frac{R_2'}{S} = 3(100)^2(2.3) = 69000 \text{ w}$$

$$P_m = P_g(1-S) = 69000 * 0.95$$
$$= 65550 \text{ w}$$

$$P_{out} = P_m - P_f = 65550 - 2300$$
$$= 63250 \text{ w}$$

$$P_{out}\Big|_{hp} = \frac{63250}{746} = 84.7\ hp$$

تحويله من الـ w للـ hp
و 746 ثابت

$$\eta = \frac{63250}{73495} = 86\ \%$$

(d)

$$T_{f.L} = \frac{P_{sf}}{\omega_s} = \frac{69000}{2\pi \times \frac{1500}{60}}$$

علشان أجيب الـ Torque بعوض
بالـ S في الحالة اللي عايزها .

$$= \frac{69000}{50\pi} = 439.5\ N.m$$

→ Starting torque at $S=1$ ⇒ T_{st} starting torq.

$$I_2' = \frac{250}{(0.215 + j0.7)} = 341.4$$

$(0.112+0.1)$

التيار عند الـ start كبير

$$P_g = 3(341.4)^2\ 0.115 = 40212\ \omega$$

$$T_{st} = \frac{P_{g\,st}}{\omega_s} = \frac{40212}{50\pi} = 256\ N.m$$

ratio of T_{st} to T_{FL} $= \frac{256}{439.5} = 0.58 = 58\ \%$

بسم الله قبل الـ أكلة.

$$n_s = \frac{120f}{P} \quad \text{rpm}$$

$$S = \frac{n_s - n_r}{n_s} \quad \text{pu "Per unit"}$$

دايماً الـ $n_s > n_r$

* at starting $(n_r = 0) \Rightarrow S = 1$
* at noload $n_r \to n_s \Rightarrow S \to 0 \Rightarrow 0 < S < 1$

$$S_{FL} = [0.03 \longrightarrow 0.06]$$

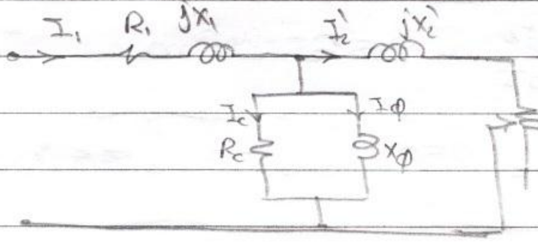
$$\therefore \frac{R_2}{S} > R_2$$

لأن الـ S رقم أقل من 1

$$\frac{R_2}{S} = R_2 + R_m$$

or $$\frac{R_2}{S} = R_2 + \frac{R_2(1-S)}{S}$$

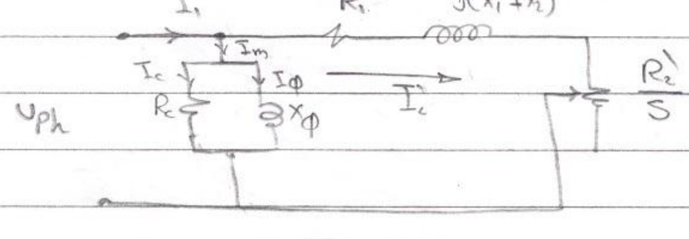
علشان دى كدة لأن انا أصلاً عندى R_2 دايماً ثابتة والـ load بيتغير فبيغير R_m



$$\frac{R_2'}{S} = R_2' + \frac{R_2(1-S)}{S}$$

Exact E. Circuit

* → Approximate Elec. circuit



$$I_m = I_c + I_\phi = \frac{V_{ph}}{R_c} - j\frac{V_{ph}}{X_\phi}$$

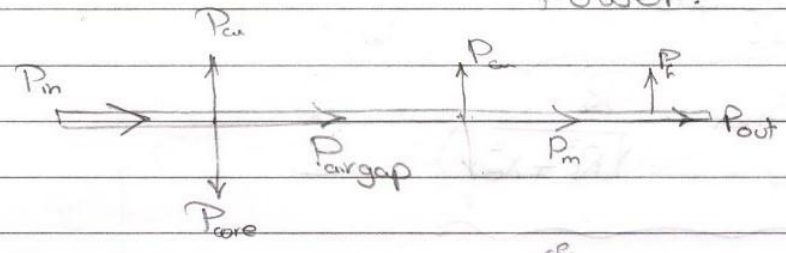
$$I_2' = \frac{V_{ph}\angle 0}{\left(R_1 + \frac{R_2'}{S}\right) + jX_{eq_r}} = \frac{V_{ph}\angle 0}{\sqrt{\left(R_1 + \frac{R_2'}{S}\right)^2 + X_{eq_r}^2}} \angle -\tan^{-1} X_{eq}/R_1 + R_2'/S$$

$$I_1 = I_m + I_2' = |I_1| \angle -\phi_1$$

$$P_{in} = 3\, V_{ph}\, I_1 \cos\phi_1$$

3phase لانه

Power. توزيع ال *



three phase

$$P_{in} = 3\, V_{ph}\, I_1 \cos\phi_1$$

stator losses

$P_{cu} = 3 I_1^2 R_1$

$+\ P_{core} = 3 I_c^2 R_c$

Air gap power

$P_g = T_d \omega_s$

$= 3 I_2'^2 \frac{R_2'}{S}$

$P_{core} = 3 I_2'^2 R_2'$

$= S P_g$

$P_m = 3 I_2'^2 R_m$

$= P_g (1 - S)$

Note: losses of iron in rotor is very small

P_{fr}

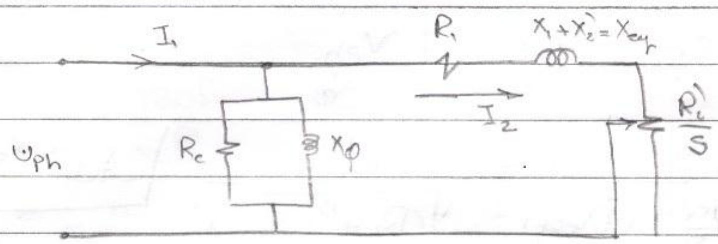
Given

P_{out}

$= T_{sh} \omega$

$\omega_m = \frac{2\pi n_r}{60}$ * $P_{Elec} = V.I$

$\omega_s = \frac{2\pi n_s}{60}$ * $P_{Mech} = T.\omega$



$$\therefore\ T_d = \frac{P_g}{\omega_s} = \frac{3 I_2'^2 R_2/S}{\omega_s} = \frac{3 R_2'}{\omega_s S} I_2'^2$$

$$= \frac{3 R_2'}{\omega_s S} \frac{V_{ph}^2}{(R_1 + \frac{R_2'}{S})^2 + X_{eq}^2}$$

To Get Max. S

$$\frac{dT_d}{dS} = 0$$

$$\boxed{\therefore\ S_{Max} = \frac{R_2'}{\sqrt{R_1^2 + X_{eq}^2}}}$$ # حفظ

$$T_{max} = \frac{3 V_{ph}^2}{3 \omega_s [R_1 + \sqrt{R_1^2 + X_{eq}^2}]}$$

لا يعتمد على R_2

* assume $R_1 = 0$ "stator"

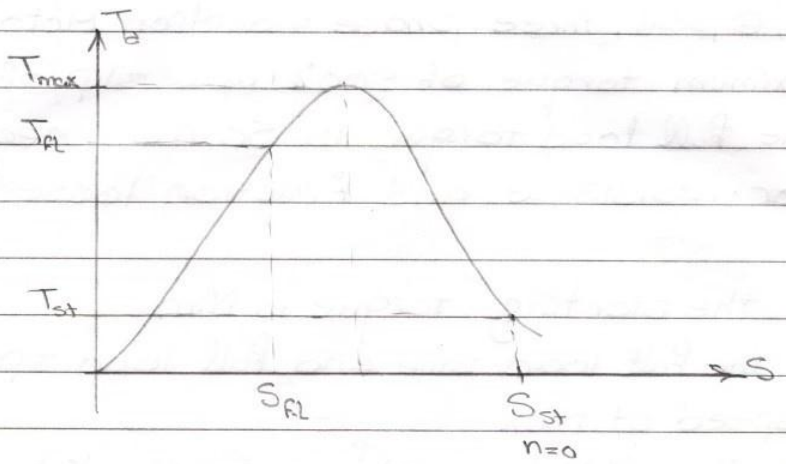
$$\therefore\ T_d = \frac{3}{\omega_s} \frac{V_{ph}^2}{(\frac{R_2'}{S})^2 + X_{eq}^2} \frac{R_2'}{S} = KS$$

$$S_{max} = \frac{R_2'}{X_{eq}}$$ #

$$T_{max} = \frac{3 V_{ph}^2}{2 \omega_s X_{eq}}$$ #

$$\frac{T}{T_{max}} = \frac{2 \frac{R_2'}{S} X_{eq}}{(\frac{R_2'}{S})^2 + (X_{eq})^2} = \frac{2}{\frac{R_2'}{S X_{eq}} + \frac{S X_{eq}}{R_2'}} = \frac{2}{\frac{S_{max}}{S} + \frac{S}{S_{max}}}$$

$$\boxed{T_{F.L} = \frac{2 T_{max}}{\frac{S_{max}}{S_{F.L}} + \frac{S_{F.L}}{S_{max}}}}$$ Given T_{max}, S_{max}



(T|S Curve)

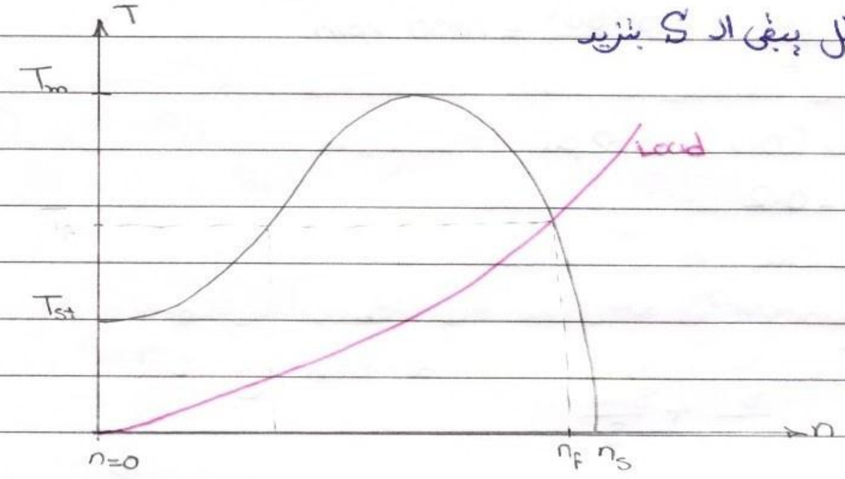
$$S = \frac{n_s - n}{n_s}$$

$$S n_s = n_s - n$$

$$n = n_s - S n_s$$

$$n = n_s(1 - S)$$

كل ما الـ n بتقل بيبقى الـ S بتزيد



s=1 (T|n curve) s=0

اتجاه زيادة الـ S

Example:-

A 50HZ, 6 pole, three phase induction Motor has a maximum torque of 200% at a slip of 0.2 if the full load torque is 50 N.m. neglect the stator resistance and fraction losses

1- Obtain the starting torque in N.m
2- Obtain the full load slip and full load speed
3- The speed at Max. torque
4- Obtain the added resistance to the rotor to obtain the max torque at starting at the sam torque
5- Obtain the Radd to change the speed at full load to 900 R.P.M

Sol:

لازم اجيبها اول علشان احتاجها

$$n_s = \frac{120f}{P} = \frac{120(50)}{6} = 1000 \ rpm$$

$T_{max} = 200\% = 2 \ pu$

$S_{max} = 0.2$

$T_{F.l} = 50 \ N.m$

(a) $$T_s = \frac{2T_{max}}{\frac{S}{S_{max}} + \frac{S_{max}}{S}}$$ at starting $S=1$

$$T_s = \frac{2(2)}{\frac{1}{0.2} + \frac{0.2}{1}} = \frac{4}{5.2} = 0.77 \ P_u$$

(b) Full load at S_f

$$T_{F.L} = \frac{2T_{max}}{\frac{S_f}{S_{max}} + \frac{S_{max}}{S_f}}$$

لأني عارف أن ال Torque عند ال full load بيكون بـ 1Pu

$$\rightarrow 1 = \frac{2(2)}{\frac{S_f}{0.2} + \frac{0.2}{S_f}} \Rightarrow \frac{S_f}{0.2} + \frac{0.2}{S_f} = 4$$

$S_f^2 + 0.04 = 0.8 S_f$

$S_f^2 - 0.8 S_f + 0.04 = 0$

$S_f = 0.746$ refused $\qquad$ $S_f = 0.053$ Accept $\qquad$ لازم ال S_f تكون اقل من S_{max}

$S_{max} > S_f$

$\therefore S_f = 0.053 \; P_u = 5.3\%$

$n_f = n_s(1 - S_f) = 1000(1 - 0.05)$
$= 950$ rpm

(b) $n_{max} = n_s(1 - S_m)$
$= 1000(1 - 0.2) = 800$ rpm.

$$R_{add} = \frac{S_2 - S_1}{S_1} R_2$$ مهم

(d) to obtain max. torque at the start at the same torque
(S₁) (S₂)

$\therefore S_1 = S_{max}$

$S_2 = S_{st} = 1$

$\therefore R_{add} = \frac{1 - 0.2}{0.2} * R_2 = 4 R_2$

(e) to change speed at full load to 900 rpm

$\therefore S = \frac{n_s - n_r}{n_s}$

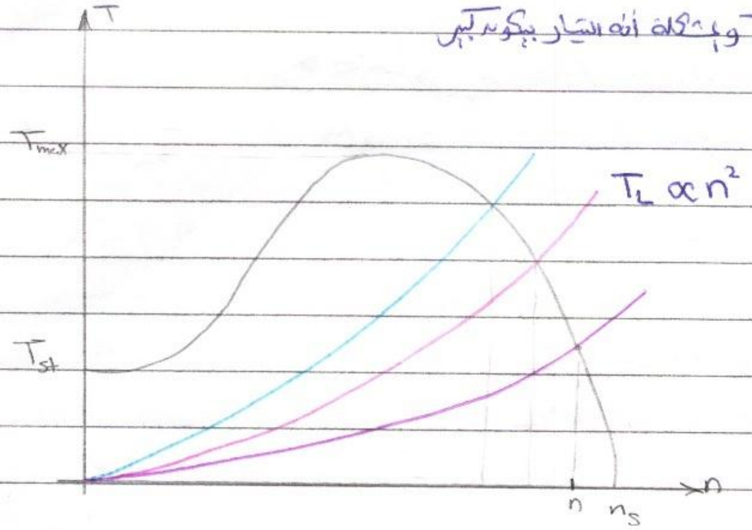
$S_{f.L} = 0.053$ calculated in (b) $\qquad$ $S|_{900} = \frac{n_s - 900}{n_s}$

$S|_{900} = \frac{1000 - 900}{1000} = 0.1$

$\therefore R_{add} = \frac{0.1 - 0.053}{0.053} R_2 = 0.88 R_2$
$\simeq R_2$

Note :-

بيهمني في أي Motor أني أكبر
الـ T_{st} ومشكلة أنه التيار بيكون كبير

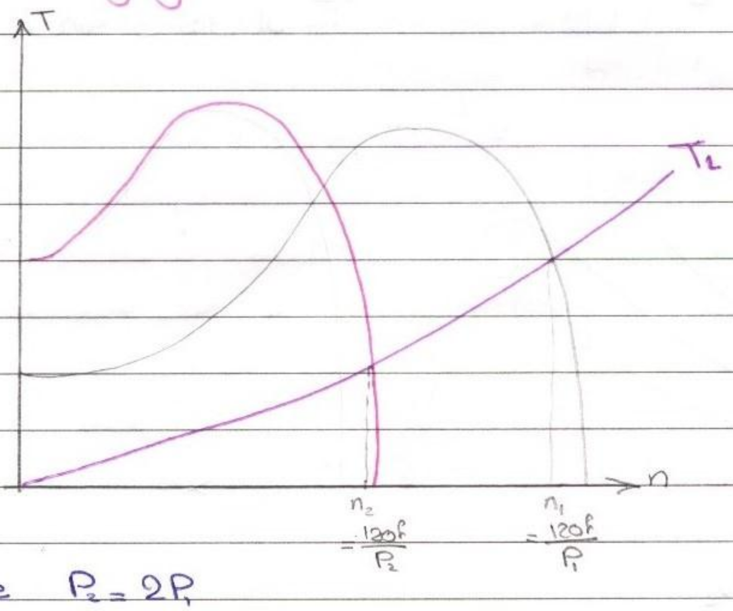


كل لما أزود الحمل بسرعة تقل

* Speed control of induction Motor.

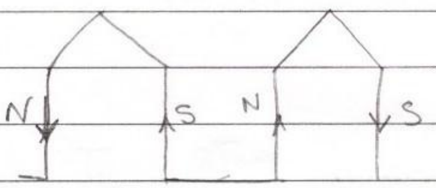
1- Pole changing " squirrel case " مع النوع ده بس
2- Line frequency control
3- line Voltage control
4- Rotor resistance control " wokned Rotor " مع النوع ده

1- Pole changing.

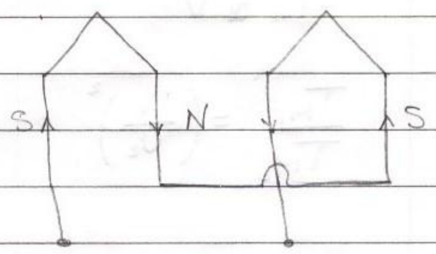


where $P_2 = 2P_1$

تغير الأقطاب بيكون
معتمد على connection

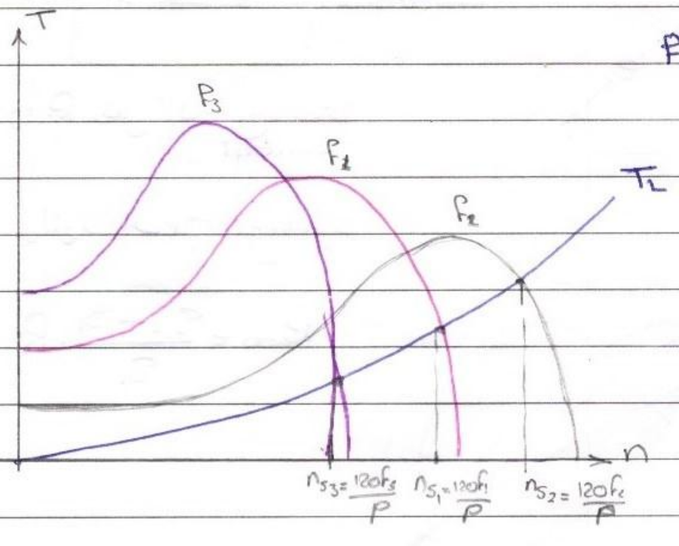


P=4



P= 2

2- frequency control أفضل طريقة مستخدمة من الآلة



$f_2 > f_1 > f_3$

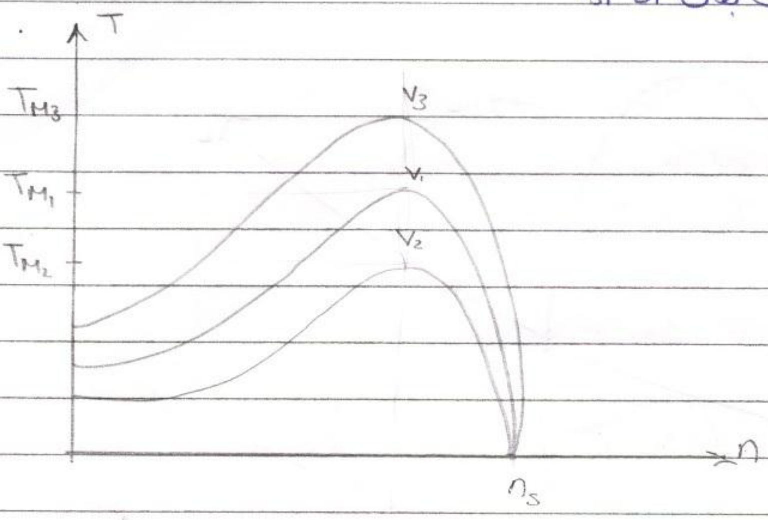
$\because T_{max} = \frac{3V_{ph}^2}{2\omega_s X_{eq}} \propto \left(\frac{V}{f}\right.$

$T_M \propto 1/f^2$

$\frac{T_{M1}}{T_{M2}} = \left(\frac{f_2}{f_1}\right)^2$

3 line voltage control

مستخدمة أكثر فى ال DC
ومشكلته أنى بقلل ال T_{st}

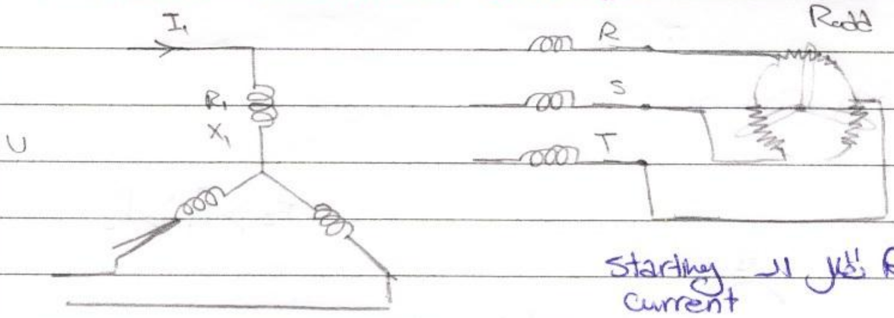


$V_3 > V_1 > V_2$

$T_m \propto V^2$

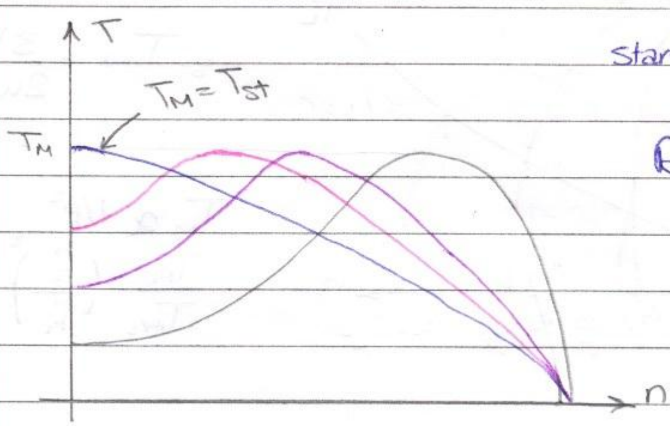
$$\frac{T_{M_1}}{T_{M_2}} = \left(\frac{V_1}{V_2}\right)^2$$

4- Rotor resistance controlle.



R_{add} بتقلل ال starting current

وتزود ال starting torque



$$R_{add} = \frac{S_2 - S_1}{S_1} \cdot R_2$$

P_o

A 50 hpower, 3 phase, 440 V, 4 pole, 60 HZ wonded rotor induction motor developed its rated torque at a speed of 1746 rpm. The max Torque is 200% and the rotor resistance = 0.15Ω, neglect rotitional losses and the stator resistance.

Cal8. 1- The slip at Max torque & the speed.

2- The starting torque in N.m

3- Radd to produce a Max Torque at starting.

Sol: $P = 4$ $f = 120$

$$n_s = \frac{120f}{P} = \frac{120(60)}{4} = 1800 \text{ rpm}$$

$$n_f = 1746 \text{ rpm}$$

$$S_f = \frac{n_s - n_f}{n_s} = \frac{1800 - 1746}{1800} = 0.03 \, P_u = 3\%$$

(a) $$T_f = \frac{2T_{max}}{\frac{S_{max}}{S_f} + \frac{S_f}{S_{max}}}$$ $\because T_{max} = 200\% = 2 \, P_u$

$$1 = \frac{2(2)}{\frac{S_{max}}{0.03} + \frac{0.03}{S_{max}}}$$

$$\frac{S_{max}}{0.03} + \frac{0.03}{S_{max}} = 4$$

$$S_{max}^2 + 9 \times 10^{-4} = 0.12 S_{max}$$

$$S_{max}^2 - 0.12 S_{max} + 9 \times 10^{-4} = 0$$

$S_{max} = 0.112$ $S_{max} = 0.008$

Accept refused

becaus S_{max} must greater then S_{fl}

$$n_{max} = n_s(1 - S) = 1800(1 - 0.112)$$
$$= 1598.4 \text{ rpm}$$

(b) $$T_{st} = \frac{2\,T_{max}}{\frac{S_{max}}{S_{st}} + \frac{S_{st}}{S_{max}}}$$

$$= \frac{4}{\frac{0.112}{1} + \frac{1}{0.112}} = 0.4425\,P_u$$

بس هو عايزها بـ N.m
فالحالة دي لازم أجيب
reffrence عشان أعوض
فيها عن الـ torque علشان يطلع
بالـ N.m
الـ refer هو الـ Td

at $P_f = 0$ ∴

∴ $P_m = P_o + P_f$

∴ $P_m = P_o = 50\ hp$

$= 50 * 746 = 37300\ N.m$

∴ $P_o = T_d\,\omega$

∴ $\omega = \frac{2\pi\ 1746}{60} = 182.84$

$$T_d = \frac{P_o}{\omega} = \frac{37300}{182.84} = 204\ N.m$$

∴ $T_M = 2\,T_d = 408\ N.m$ ($2P_u$)

$T_{st} = 0.4425\,(204) = 90.27\ N.m$

(3) R_{add} to produce Max torque at St. (S_1) to S_2

$$R_{add} = \frac{S_2 - S_1}{S_1} R_2 = \frac{1 - 0.112}{0.112}(0.1) = 0.793$$

http://www.com-dep.tk/